mixing the RNA and viral protein, infectivity could be demonstrated for a period of 18 hours, while the infectivity of the RNA preparation alone, starts decreasing after the 3rd hour. Specificity of protein action is quite apparent because on mixing the infectious RNA with protein isolated from uninfected cells, there is loss of infectivity of the RNA component after the 3rd hour as a result of progressive denaturation.

The progeny produced by the infectious ribonucleic acid (RNA) corresponded to the parent type strain with two main differences in biological properties: (1.) A marked divergence in infectivity titer in the chick kidney culture with the parent line being able to grow to a much higher titer, $10^{5.3}$ $TCID_{50}$ per ml (a difference of two log); (2.) a loss of ability to propagate in the allantoic cavity of embryonate eggs. However, inoculation into the amniotic cavity resulted in a titer of $10^{2.C}$ EID_{50} per ml.

Although this study is still in its infancy, it is hoped that the approach will considerably clarify the relationships existing between RNA and protein of different strains of influenza virus and will set the stage for a possible molecular interpretation of the antigenic shift of influenza virus.

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*ON A SYMMETRY IN WEAK INTERACTIONS**

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1. *Introduction.*—The V-A theory of weak interactions[1] appears to be on an extraordinarily sound experimental footing in so far as the strangeness-conserving processes are concerned.[2] The decay process: $\mu \rightarrow e + \nu + \bar{\nu}$ leads uniquely to a V-A interaction for the physical fermions and, since no strong interactions are involved, to a V-A interaction for the "bare" fermions; unfortunately, it is not decided whether the charge-exchange or charge-retention order for the current is to be chosen since both orders lead to identical results for the V-A interaction. The nuclear beta decay experiments require a (V − 1.2 A) interaction in the charge-exchange order for the baryon and lepton currents separately; since the vector part of the interaction for nuclear beta decay is equal (within a few per cent) to the vector part of the interaction for muon decay, and since virtual pion effects can in principle explain the different coefficient in front of the axial vector part of the

interaction, it is indicated that the bare fermion interaction in nuclear beta decay is also V-A. Finally, the recent experimental findings[3] on the ratio of the processes: $\pi \rightarrow e + \nu$ to $\pi \rightarrow \mu + \nu$ argue in a striking fashion for the equality of the couplings of the ($\mu\nu$) and ($e\nu$) lepton pairs to the (np) baryon pair for the axial vector part of the interaction; since the pion renormalization effects cancel out, this equality must hold for the bare couplings. If we furthermore take cognizance of the fact that such processes as: $\mu \rightarrow 3e$, $\mu + p \rightarrow p + e$, and $\mu + n \rightarrow n + e$ are not observed, we can conclude that a satisfactory explanation of all strangeness-conserving weak processes would be obtained by postulating a universal V-A interaction among the three charge exchange pairs ($e\nu$), ($\mu\nu$), (np).

The situation regarding the strangeness-nonconserving processes is less clearcut both because the experimental data are much more meager and also because the theoretical ambiguities are greater. If one adds the strangeness-nonconserving baryon pair (Λp) to the other three charge-exchange pairs, one can in principle explain[4] both the leptonic and nonleptonic decay modes of the strange baryons (Λ, Σ, Ξ) and the strange meson (K). One can even argue that the total evidence from the strange particle decays is in favor of comparable amounts of V and A interaction for the bare fermions despite the uncertain status of the different renormalization corrections for the different processes. However, it is not clear why such strangeness-nonconserving charge-exchange baryon pairs as (Σ^0, p) and (Σ^-, n) should not be included and it is not even absolutely certain that the charge-exchange pair (Σ^+, n) should be excluded. One uncertain experimental point of particular importance is whether the $\Delta I = 1/2$ selection rule first suggested by Gell-Mann holds for the nonleptonic decay modes of the strange particles. This isotopic spin selection rule requires an equal admixture of the charge-exchange four-fermion coupling (Λp)(np) and the charge-retention four-fermion coupling (Λn)(nn). The present experimental data are consistent with this selection rule but are also equally consistent with the $I = 1/2$ strangeness nonconserving current rule proposed by other authors.[5] The arguments for using charge-exchange currents for the strangeness-nonconserving processes are therefore not as strong as for the strangeness-conserving processes.

In order to eliminate the theoretical ambiguity for the strangeness-nonconserving processes, we shall adopt the viewpoint that the (Λ, n, p) baryon triplet is the complete analogue of the (μ, e, ν) lepton triplet in so far as the weak interactions are concerned. Authors like Sakata[6] and Okun[7] have proposed specific models in which the Σ and Ξ hyperons and the π and K mesons are regarded as bound states of Λ, n, p, and their antiparticles. Our remarks will not depend on the choice of a specific model for the strong interactions.

2. Symmetry Principle between the Baryon and Lepton Triplets.—The (Λ, n, p) baryon triplet—in order of decreasing mass—appears to be the minimum number of strongly interacting particles which are necessary to explain conservation of charge, isotopic spin, and strangeness (in strong interactions). In weak interactions, conservation of isotopic spin and strangeness no longer hold and the baryon triplet (Λ, n, p) bears a striking similarity to the lepton triplet (μ, e, ν) in several respects. In the first place, the mass difference between the component of the isotopic doublet (n, p) is of the same order of the mass difference between the members of the pair (e, ν) and both are probably explicable in terms of electromagnetic self-energies. Secondly, the mass difference between the third member of the baryon triplet, Λ, and the isotopic doublet (n, p) is of the same order as the mass difference between μ and the (e, ν) pair; there seems to be a connection between the large mass of the muon and the role of strangeness in weak interactions. Pursuing this analogy, we would argue that the mass difference between Λ and the nucleon cannot be explained by any of the known self-energy effects, since the corresponding mass difference between muon and electron is apparently not due to any of these self-energy effects (strong, electromagnetic, or weak). Furthermore, we would not expect any leptons heavier than the muon since a baryon triplet suffices to account for the conservation laws in strong interaction; by the same token, it would not be surprising to find additional baryons and bosons (mesons) which are more complicated composite systems of the three fundamental baryons.

In order to give greater meaning to the above remarks and to suggest explicit experimental tests, we postulate the following symmetry principle: all weak interactions are invariant under the following simultaneous transformation:

$$\Lambda \rightleftarrows \mu, \qquad \mathrm{n} \rightleftarrows \mathrm{e}, \qquad \mathrm{p} \rightleftarrows \nu \tag{A}$$

In this note, we investigate the consequences of the transformation (A). We shall find that (A) does not contradict any of the known facts and leads to some interesting predictions which can be tested.

We classify in Tables 1 and 2 all possible four-fermion interactions in accordance with principle (A); Table 1 lists the lepton-lepton interactions (and consequently also the baryon-baryon interactions) and Table 2 lists the baryon-lepton interactions (and consequently the lepton-baryon interactions). In these tables we have omitted all interactions which can be derived by permutations of the spinors i.e., we do not distinguish among $(\bar{\psi}_1\psi_2)(\bar{\psi}_3\psi_4)$, $(\bar{\psi}_1\psi_4)(\bar{\psi}_3\psi_2)$, $(\bar{\psi}_3\psi_2)(\bar{\psi}_1\psi_4)$, and $(\bar{\psi}_3\psi_4)(\bar{\psi}_1\psi_2)$. We have also indicated whether the weak process has been observed (favorable), could have been observed but has not been observed (unfavorable), or for which there is no evidence either way (unknown). Under remarks we have noted illustrations of weak processes which follow from the postulated four-fermion interactions.

3. Discussion.—The following comments can be made concerning Tables 1 and 2.

(1) The symmetry principle (A) reduces to 4 the number of four-fermion interactions required to explain all the observed weak processes; this is to be compared to the 6 originally required by the Gell-Mann-Dallaporta tetrahedron.

(2) The four-lepton interactions $(\bar{\mu}e)$ $(\bar{e}e)$ and $(\bar{\mu}e)$ $(\bar{\mu}\mu)$ are in the unfavorable class. The first interaction appears to be forbidden because the decay $\mu^- \rightarrow e^- + e^- + e^+$ is never observed. The second interaction $(\bar{\mu}e)$ $(\bar{\mu}\mu)$ must also be forbidden for the same reason because it gives rise to an effective $(\bar{\mu}e)$ $(\bar{e}e)$ due to the virtual electromagnetic interaction. An estimate shows that this effective $(\bar{\mu}e)$ $(\bar{e}e)$ is of the order of $(1/2\pi)$ $(e^2/4\pi)$ ln $[(\lambda/m\mu)^2 + 1]$ compared to the original interaction, where λ is the cutoff momentum. Even if λ is taken equal to the muon mass, the four-lepton interaction $(\bar{\mu}e)$ $(\bar{\mu}\mu)$ must be forbidden to explain the experimental upper limit on the decay $\mu \rightarrow 3e$. It perhaps should be remarked that the interactions $(\bar{\mu}e)$ $(\bar{\mu}\mu)$ and $(\bar{\mu}e)$ $(\bar{e}e)$ would give rise to the decay $\mu \rightarrow e + \gamma$ although this would be of order $(e^2/4\pi)^3$ and consequently very small. If we

TABLE 1

LEPTON AND BARYON INTERACTIONS

Type	Interaction	Remarks
Favorable	$(\bar{\mu}\nu)(\bar{\nu}\bar{e}) \longleftrightarrow (\bar{\Lambda}p)(\bar{p}n)$	$\mu^- \to e^- + \nu + \bar{\nu}$ $\Lambda \to p + \pi^-$
Unfavorable	$(\bar{\mu}e)(\bar{e}e) \longleftrightarrow (\bar{\Lambda}n)(\bar{n}n)$	$\mu^- \to e^- + e^- + e^+$ $\Delta I = {}^1/_2$ selection rule
	$(\bar{\mu}e)(\bar{\mu}\mu) \longleftrightarrow (\bar{\Lambda}n)(\bar{\Lambda}\Lambda)$	$\mu^- \to e^- + e^- + e^+$
	$(\bar{\mu}e)(\bar{\mu}e) \longleftrightarrow (\bar{\Lambda}n)(\bar{\Lambda}n)$	$e^- + e^- \to \mu^- + \mu^-$ $K_1^\circ - K_2^\circ$ mass difference
Unknown	$(\bar{\mu}\mu)(\bar{\mu}\mu) \longleftrightarrow (\bar{\Lambda}\Lambda)(\bar{\Lambda}\Lambda)$	
	$(\bar{\mu}\mu)(\bar{e}e) \longleftrightarrow (\bar{\Lambda}\Lambda)(\bar{n}n)$	
	$(\bar{\mu}\mu)(\bar{\nu}\nu) \longleftrightarrow (\bar{\Lambda}\Lambda)(\bar{p}p)$	
	$(\bar{e}e)(\bar{e}e) \longleftrightarrow (\bar{n}n)(\bar{n}n)$	
	$(\bar{e}e)(\bar{\nu}\nu) \longleftrightarrow (\bar{n}n)(\bar{p}p)$	$e + \nu \to e + \nu$
	$(\bar{\nu}\nu)(\bar{\nu}\nu) \longleftrightarrow (\bar{p}p)(\bar{p}p)$	

TABLE 2

BARYON-LEPTON INTERACTIONS

Type	Interaction	Remarks
Favorable	$(\bar{p}n)(\bar{e}\nu) \longleftrightarrow (\bar{\nu}e)(\bar{n}p)$	$n \to p + e^- + \bar{\nu}$
	$(\bar{\Lambda}p)(\bar{\nu}\mu) \longleftrightarrow (\bar{\mu}\nu)(\bar{p}\Lambda)$	$K^+ \to \mu^+ + \nu$
	$(\bar{p}n)(\bar{\mu}\nu) \longleftrightarrow (\bar{\nu}e)(\bar{\Lambda}p)$	$\mu^- + p \to n + \nu$ $\Lambda \to p + e^- + \bar{\nu}$
Unfavorable	$(\bar{\Lambda}n)(\bar{\mu}e) \longleftrightarrow (\bar{\mu}e)(\bar{\Lambda}n)$	$K_2^\circ \to \mu^- + e^+$
	$(\bar{\Lambda}n)(\bar{e}\mu) \longleftrightarrow (\bar{e}\mu)(\bar{\Lambda}n)$	$K_2^\circ \to \mu^+ + e^-$
	$(\bar{n}n)(\bar{\mu}e) \longleftrightarrow (\bar{e}e)(\bar{\Lambda}n)$	$\mu^- + n \to e^- + n$ $K_2^\circ \to e^- + e^+$
	$(\bar{p}p)(\bar{\mu}e) \longleftrightarrow (\bar{\nu}\nu)(\bar{\Lambda}n)$	$\mu^- + p \to e^- + p$ $K_2^\circ \to \pi^\circ + \nu + \bar{\nu}$
	$(\bar{\Lambda}\Lambda)(\bar{\mu}e) \longleftrightarrow (\bar{\mu}\mu)(\bar{\Lambda}n)$	$K_2^\circ \to \mu^+ + \mu^-$
Unknown	$(\bar{\Lambda}\Lambda)(\bar{\mu}\mu) \longleftrightarrow (\bar{\mu}\mu)(\bar{\Lambda}\Lambda)$	
	$(\bar{p}p)(\bar{\mu}\mu) \longleftrightarrow (\bar{\nu}\nu)(\bar{\Lambda}\Lambda)$	
	$(\bar{p}p)(\bar{\nu}\nu) \longleftrightarrow (\bar{\nu}\nu)(\bar{p}p)$	$\nu + p \to \nu + p$
	$(\bar{n}n)(\bar{\nu}\nu) \longleftrightarrow (\bar{e}e)(\bar{p}p)$	
	$(\bar{\Lambda}\Lambda)(\bar{e}e) \longleftrightarrow (\bar{\mu}\mu)(\bar{n}n)$	
	$(\bar{n}n)(\bar{e}e) \longleftrightarrow (\bar{e}e)(\bar{n}n)$	

accept these statements, our symmetry principle (A) now predicts that the four-baryon interactions $(\bar{\Lambda}n)$ $(\bar{n}n)$ and $(\bar{\Lambda}n)$ $(\bar{\Lambda}\Lambda)$ are forbidden. This implies that the only possible nonleptonic weak interaction which involves a half-integral change of isotopic spin is $(\bar{\Lambda}p)$ $(\bar{p}n)$ and hence the $\Delta I = {}^1/_2$ selection rule of Gell-Mann cannot be valid. In general, the nonleptonic decays will involve a mixture of $\Delta I = {}^1/_2$ and $\Delta I = {}^3/_2$. More detailed discussion of this last point will be found in other papers.[4]

(3) We have placed the four lepton interaction $(\bar{\mu}e)$ $(\bar{\mu}e)$ in the unfavorable class because its analogue (according to (A)), the four-baryon interaction $(\bar{\Lambda}n)$ $(\bar{\Lambda}n)$, is unfavorable. The latter interaction gives rise to a so-called $\Delta S = 2$ transition and therefore yields too large a mass difference between K_1° and K_2° to be consistent with experiment.[8] Our statement concerning the forbiddenness of $(\bar{\mu}e)$ $(\bar{\mu}e)$ could be checked in principle by looking for the process $e^- + e^- \to \mu^- + \mu^-$ but unfortunately the threshold energy for this reaction is 44 Bev for the laboratory electron. Another test would be to study the reaction $e^- + \mu^+ \to e^+ + \mu^-$ but the cross section is of the order of 10^{-45} cm^2.

4.—The self-conjugate baryon-lepton interactions $(\bar{\Lambda}n)$ $(\bar{\mu}e)$ and $(\bar{\Lambda}n)$ $(\bar{e}\mu)$ are unfavorable because the decay modes $K_2^\circ \to \mu^- + e^+$ and $K_2^\circ \to \mu^+ + e^-$ are unobserved.

5.—The baryon-lepton interactions $(\bar{n}n)$ $(\bar{\mu}e)$ and $(\bar{p}p)$ $(\bar{\mu}e)$ are unfavorable because the reactions $\mu^- + n \rightarrow e^- + n$ and $\mu^- + p \rightarrow e^- + p$ are not observed. Similarly, the baryon-lepton interaction $(\bar{\Lambda}\Lambda)$ $(\bar{\mu}e)$ is unfavorable because it will give rise to an effective $(\bar{n}n)$ $(\bar{\mu}e)$ or $(\bar{p}p)$ $(\bar{\mu}e)$ interaction via the strong interactions. This would imply, in accordance with our principle (A), that the baryon-lepton interactions $(\bar{\Lambda}n)$ $(\bar{e}e)$, $(\bar{\Lambda}n)$ $(\bar{\mu}\mu)$, and $(\bar{\Lambda}n)(\bar{\nu}\nu)$ are unfavorable. This is consistent with the experimental absence of the decays: $K_2^\circ \rightarrow e^- + e^+$, $K_2^\circ \rightarrow \mu^- + \mu^+$, and $K_2^\circ \rightarrow \pi^\circ + \nu + \bar{\nu}$.

6.—The remaining unknown four-lepton, four-baryon and baryon-lepton interactions represent weak scattering reactions with cross sections of the order of 10^{-45}cm^2. Experiments to decide whether these interactions are favorable or not will be very difficult.

We have found, therefore, that the symmetry principle (A) between the baryon triplet (Λ, n, p) and the lepton triplet (μ, e, ν) is completely consistent with existing experiments. Favorable interactions lead to favorable interactions and the negative is also true. The success of principle (A) makes it tempting to introduce formally the notion of isotopic spin and weak hypercharge for leptons. Assigning isotopic spin one-half for the (e, ν) pair and zero isotopic spin for the muon, the charge Q for any member of the baryon and lepton triplet can be written as:

$$Q = I_3 + (T + B - L)/2 \qquad \text{(B)}$$

This formula holds for both baryons and leptons if we assign $T = -1$ for the muon and $T = 0$ for the electron and neutrino, and if we identify T with the strangeness S in the case of the baryon. L (or B) is the lepton (or baryon) number and I_3 is the third component of the isotopic spin. If we adopt equation (B), the reaction $e^- + e^- \rightarrow \mu^- + \mu^-$, for example, would be forbidden because of the selection rule $\Delta T = 2$, which corresponds to $\Delta S = 2$.

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